

The History and Future of Radio

By Dr. John F. Catalano

Today, in the year 2001, most of us think of a desktop receiver as a few microchips, a display, some control knobs and a loudspeaker. Others, who are computer-based, just think of a computer-controlled receiver as a black-box with a cable connecting it to a computer. And yet owners of wide-band handheld receivers, such as the R2 or VR-500, think of it as portable, cigarette-pack size and battery operated. In all cases the radio receivers of today are simple to operate but complex in the technology they utilize.

This was not always the case. As we will see in this two-part feature on the past, present and future of radio, early radio wave reception was just the opposite of today's situation. The early receivers were complex to operate but simple in the technology it employed. Let's go back to the roots of radio and the people who shaped its future.

The First Spark

At the end of the 19th century, when Heinrich Hertz sent a radio signal across empty space, he utilized the then revolutionary spark gap technology.

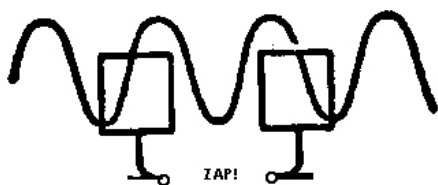


Figure 1 – Hertz Spark Gap Receiver – Pre-1900

The transmitter consisted of a telegraph key, a spark gap, and tuning coils. The tuning coils were connected to a long, horizontal wire, which acted as the transmitting antenna. A source of electricity is connected to a telegraph key, which in turn is connected to the spark gap. The spark gap was nothing more than two conductors spaced close enough together so that the supplied electricity would ionize the air between the conductors. This resulted in a spark being generated between the conductors. The spark gap turned on and off at a low audio rate. In

other words, it buzzed. This, in turn, causes the transmitter's tuning coils to generate a radio wave having a range of frequencies.

Hertz used a similar spark gap arrangement as the receiver. The spark gap receiver was "tuned" to the frequency(s) of the transmitter by adjusting LC networks consisting of coils and capacitors. Coarse tuning was obtained by adjusting the spacing of the spark gap conductors. The "tuning" approach was very empirical and required patience and a measure of luck. If tuned correctly, a small spark was generated at the receiver by the transmitted spark.

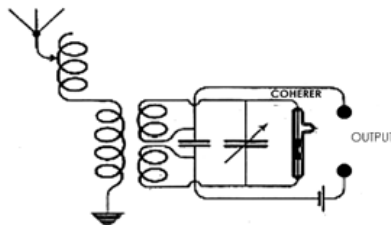


Figure 2 – Radio – wire coils, capacitor, coherer and headphone circa 1900

Ships began to carry spark gap transmitters and receivers, the importance of which gained widespread acceptance after the *Titanic* sank.

DXing with the Spark Gap

When reception over longer distances was attempted, a more sensitive indicator, or detector, was needed. Here the inventors of the day modified a device that was used to protect electrical devices, such as telegraph lines, from lightning.

The long distance, high sensitivity detector device was called the coherer. It consisted of a glass tube loosely filled with metal filings. A wire was sealed into each end of the glass tube so the wire ends were in contact with the metal filings. When the filings are lying loosely in the tube, the coherer shows a high resistance to the flow of electric current. When connected to the tuning coils, and in the presence of a radio signal, the filings will rearrange themselves to form a low resistance path. This low resistance condition will continue after the radio signal goes away and as long as the glass tube is not physically disturbed.

If the coherer is tapped with a small object, the metal filings will be rearranged back into their "off," or high resistance condition. So, the early receivers used a sensitive relay in series with the coherer to boost the current high enough to operate a telegraph sounder.

The coherer and the sounder were arranged together so that whenever the sounder "clicked," it would reset the coherer. In this way, the person at the receiver would hear buzzes of long and short duration, corresponding to the message being sent at the transmitter. Even with this simple setup, messages could be sent over long distances without wires and over water; also, where it was difficult or impossible to place a telegraph wire.

In those days, around 1900, a radio was a few coils of wire, a detector and a pair of headphones. See Figure 2.

Experimenters wanted to send voice over long distances. The spark gap system could only be "on" or "off" and therefore was unsuited for audio (voice) signals.

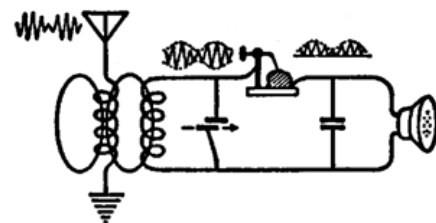


Figure 3 – Crystal Diode Detector-based Radio Circuit circa 1907

Around 1906 a high-powered a-c generator (alternator) was developed using a high-enough frequency to be used as a voice transmitter. These were the earliest broadcast transmitters. But the coherer was an unsatisfactory detector for receiving audio because it, too, was strictly an "on" or "off" device.

The "Detector" Search

In an attempt to find a suitable detector for audio signals, many different types of materials were placed in the circuit between the tuning coils and the telephone receiver (or headphones). Those that worked had the property of rectifi-

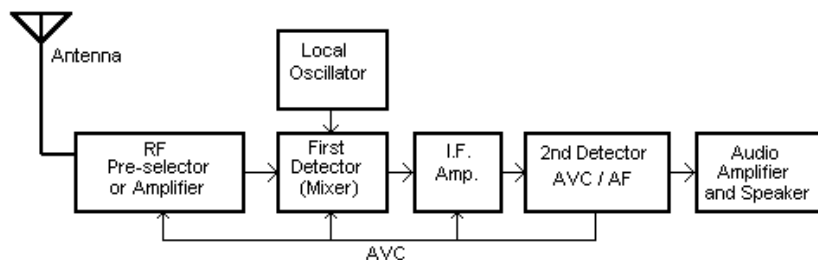


Figure 4 – Armstrong's Superheterodyne circa 1918

cation; that is, electric current passed through the material in one polarity or direction but was blocked (or partially blocked) in the opposite direction. Some detectors were crystals like galena, silicon, carborundum and germanium.

Fessenden even invented an electrolytic detector using a jar filled with an acid. A platinum wire was mechanically adjusted to barely touch the surface of the liquid.

But none of the inventions provided a reliable, easy-to-use voice detector, and the search continued.

The Industrial Drone's Brilliance

Now, before all this interest in radio had occurred, Thomas Edison was hard at work perfecting his incandescent electric light bulb. One factor that limited bulb life was the blackening of the inside of the glass bulb, which occurred gradually over the life of the bulb. In an attempt to reduce or eliminate the blackening, Edison placed a metal plate inside the bulb along with the filament. He ran a wire from the plate through the glass of the bulb. This allowed him to apply a voltage between the filament and the metal plate.

Unfortunately, the experiment didn't reduce bulb blackening. However, it did result in the discovery of the Edison effect: current flowed when the plate was positive and the filament was negative, and current would not flow when the plate was negative and the filament was positive.

Although he had inadvertently invented the vacuum tube rectifier, Edison could find no practical use for it at the time. This was to be the breakthrough detector that radio experimenters were trying to develop.

If At First You Don't Succeed ...

Marconi was a charismatic, intelligent entrepreneur who is well remembered by the public as the "father" of radio. But Marconi's success in radio occurred only after he had a string of business failures using capital raised from his Italian father's family connections. His other business results were so abysmal that he was forced to travel to England and enlist the financial backing of his English mother's family. Have you ever wondered why the Italian Marconi started a radio business in England? Now you know. He had creative people working for him, such as Sir Ambrose Fleming, who invented products on his behalf.

Around 1905 Marconi and company were also looking for the best possible detector for their radios. Sir Ambrose Fleming, who then

worked for Marconi, dusted off the Edison effect, which Marconi had purchased earlier from Edison "lamp," and discovered that it made a good radio frequency detector! It was then patented as the Fleming valve consisting of a cathode (filament) and a plate. This device was later to be known as a diode detector, or two-electrode vacuum tube, and gave birth to the vacuum tube (valve) technology and industry.

Vacuum tube based receivers were to become commonplace in all radio applications for the next 55 years! The new vacuum tube technology not only enabled a new, more sensitive detector, it also provided the Holy Grail of electronics – amplification.

Vacuum Man

Lee DeForest, amidst some controversy with Fleming, developed the triode or three-electrode vacuum tube with a cathode (filament), grid and plate. The grid is mounted between the cathode and the plate. The triode vacuum tube had one important characteristic that no previous device had exhibited: it made weak audio or radio frequency signals stronger. This 1907 invention may have been the single, most important event in shaping the history of radio.

Now with stages of vacuum tubes in amplifying, detection and oscillating circuits, the modern radio was beginning to take shape.

The Hero of Modern Radio

On September 22, 1912, encouraged by his work on the triode at Columbia University, Armstrong started a series of experiments, carried out in his attic. From this came the vacuum-tube oscillator, which was the first reliable and versatile generator of continuous waves. This principle resulted in the world's first radio capable of receiving weak radio waves from hundreds or thousands of miles away.

Due to the limited frequency capabilities of the early vacuum tubes, Armstrong devised a circuit which used a technique known as "mixing" to reduce the frequency requirements of the amplifying elements of a radio receiver. It was long known in the physics community that when two electromagnetic waves of different frequencies interact they could combine to produce a new wave which is either the sum or the difference of the two initial frequencies. Armstrong cleverly used this principle. He reasoned that by having an oscillator section in a receiver close to that of the desired radio station frequency, the radio station signal could interact with the receiver's "local" oscillator. Figure 4 is the block diagram of a superheterodyne receiver.

The Super Invention

The resulting "mixed" signal would have a frequency equal to the difference of the local oscillator and the radio signal frequency. Since the frequencies of the local oscillator (LO) and the radio station were close, the resulting mix signal, or intermediate frequency (IF), would contain all the modulation of the original signal, BUT be a much, much lower frequency. This lower frequency easily allowed vacuum tubes to provide amplification.

If the initial frequency was very high, relative to the maximum tube operating frequency, multiple IF stages could be used to reduce to the resulting signal to a manageable frequency. These stages are sometimes referred to as conversion stages. So if a receiver is designed as a dual conversion radio, it has two IFs with their corresponding local oscillators. Typical intermediate frequencies for the superheterodyne receivers from the 1950s until recently are 455 kHz and 10.7 MHz.

Early in 1918, Armstrong built the first superheterodyne radio. It had eight tubes. Just prior to entering the military, Armstrong delivered a detailed paper on the heterodyne principle. While in London, the question arose regarding reception on shortwave, given the fact that the tubes available then were incapable of amplifying above 1,000,000 cycles per second (hertz). After trying the heterodyne principle again, it occurred to Armstrong to mix a vacuum tube generated signal with the incoming radio wave in the first stage of the radio, to produce a signal low enough in frequency to be easily amplified by the tubes. Thus was born a radio which was not restricted to the then-popular longer radio waves.

The superheterodyne circuit was patented by Armstrong and licensed to RCA, Radio Corporation of America. When Armstrong had a complete receiver ready to demonstrate, he went to RCA. The exclusive RCA superheterodyne hit the stores in March 1924. Armstrong retained amateur and experimental rights to all his inventions. Mostly through the efforts of radio amateurs, this insured the rapid advancement of communications technology.

Having this patent helped RCA take a competitive advance in the home radio market, which RCA profitably enjoyed for years.

A major complaint of broadcast radio lis-

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SWBC Schedules - Broadcast frequencies and programs, updated weekly+... \$35/year
 Smart R8 Control - Smart control for the Drake R8/R8A/R8B... \$250us/\$400us/\$600us
 Smart Icom Control 32 - for IC-R75... \$600us
 Smart NRD Control 32 - for NRD-535/545... \$600us
 Smart Kenwood Control 32 - for R-5000... \$600us
 Smart Lowe Control 32 - for HF-150... \$600us
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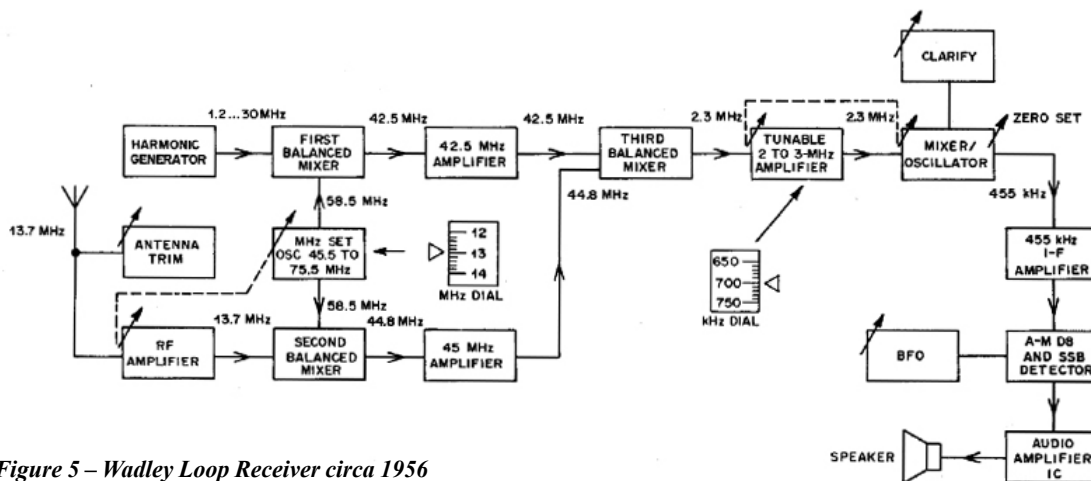


Figure 5 – Wadley Loop Receiver circa 1956

teners in those days was the presence of unwanted noises or “static.” Armstrong turned his attention to this problem. Again going against common thinking at the time, in 1933 Armstrong invented wide band frequency modulation (FM), which is still the standard for most point-to-point, two-way VHF/UHF communication.

Until the advent of high frequency microchips in the mid 1980s, Armstrong’s superheterodyne circuit was still widely used. Even solid state receivers utilized this method long after the vacuum tube technology was dead. We, and the receiver designs of today, still owe much to Edwin Armstrong.

Wadley Loop – Accurate Analog Tuning!

As a result of advances in vacuum tube technology and the intrinsic design of the superheterodyne receiver with its mixer and independent multistage concept, great advances in sensitivity and selectivity were realized.

However, the dream of every radioman was to have a receiver that they could tune to an exact frequency. Due to the temperature drift inherent in the components of the local oscillator, together with thermal aging of the tuned circuits in successive receiver stages, the analog tuning scale could not always be counted on for its accuracy.

These inaccuracies resulted in the need for the user to “tune about” the printed dial frequency in order to actually receive a station actually transmitting on the dial frequency. The goal was to design a receiver that had frequency dial marking that were always reliable. An accurate tuning system, without the need for guesswork and knob twiddling, was the goal.

Most receivers add a second “fine” tuning, bandspread knob. Although helpful for separating station, it simply added to the real tuned frequency confusion.

In the 1950s, Dr. Trevor Wadley, professor of electrical engineering at a South African university, devised a unique multiple frequency comb approach to generate the local oscillators. The Wadley loop utilized a harmonic multiplier, which generated a series of frequencies across the range of the receiver. The remainder of the receiver design still followed Armstrong’s superheterodyne (mixer) design. See Figure 5.

The Wadley Loop at Work

For illustration only, if we consider a radio designed to cover 2 to 30 MHz, the multiplier would generate a comb of discrete frequencies every 1 MHz from 2 MHz to 30 MHz. A phase lock loop is then used to “pick out” the desired coarse frequency.

A very stable, easily generated, low frequency, fine tune oscillator is then used to tune between the comb generated frequencies. For example, with an intermediate frequency of 455 kHz, the fine tune oscillator would only have to tune accurately and linearly over a 1 MHz range (from 1.455 MHz to 2.455 MHz). Restricting the range to 1 MHz, instead of the entire receiver range of 28 MHz, gave a quantum leap in analog dial tuning accuracy.

Of course, the added circuitry was state of the art at the time and added complexity and cost. This may have been what discouraged every US and European radio company that was presented with the concept. For a number of years no major radio company took the offer of patent licensing from the inventors.

The Rascal Success Story

By 1955, a relatively new radio company was trying to break into the European military market. Started on the concept of refurbishing and rebuilding leftover World War II radios, the company was bidding on a UK Royal Navy receiver contract. The company was up against some well-known names, like GEC-Marconi and Collins, and needed a unique “hook” to get the contract.

In a very gutsy move, the United Kingdom Company, Rascal, designed their proposed naval receiver around the Wadley loop and its promise of superior tuning accuracy. After some initial tense moments, the Navy chose Rascal and the Wadley loop, and the now famous RA-17 was born.

Although Rascal’s implementation of this circuit was based around vacuum tube (valve) technology, in the 1970s the Japanese company Yaesu released the solid state, consumer version of the Wadley loop, the FRG-7. Yaesu’s FRG-7 is credited with, almost single-handedly, reinvigorating the shortwave industry. The FRG-7 was extremely popular during the 1970s and 80s.

It was so popular that it was re-badged and available to every US household via the Sears catalog. Drake produced the SSR-1 receiver, and Tandy the DX-300, both using the Wadley loop circuit. However, the use of the Wadley loop was relatively short-lived, as integrated circuit complexity grew while costs dropped.

Thank You, CB Radio

Digital displays with keyboard entry are commonplace today. But how many of us realize that we owe this technology to CB (citizen band)

radio?!

In the late 1950s, CB radio really took off in the US. It had 23 channels in the 27 MHz band. Vacuum tubes were the active circuit elements with two quartz crystals, one for the transmitter and one for the receiver’s LO, were required for each channel desired.

But CB radio had a great resurgence in the early 1970s with the “moon-landing” generation. The US government (FCC) expanded the CB channels to 40. Around this time, semiconductor companies such as Motorola, TI and National were looking for a high volume product that could utilize their newly developed digital integrated circuit (IC) technology.

The concept of providing all the circuitry in a single IC to provide 40 channels with only three crystals was economically very appealing to the radio manufacturers.

Synthesized Digital Receivers

A circuit called a phase lock loop (PLL) had been used in high-end military and professional radios. It consisted of a circuit, which would compare the output of a voltage-controlled oscillator (VCO) with the desired digitally “dialed-in” frequency. The difference between the two generated an output voltage corresponding to the magnitude and sense of the difference. This was then sent to the voltage-controlled oscillator for its automatic adjustment, resulting in a match between the digitally dialed-in desired frequency and VCO output. Using this method, with careful design any range of frequencies could be simply and accurately synthesized.

Using phase lock loop techniques the synthesized CB radio was born, with National Semiconductor leading the way in the CB world with their two-chip CB synthesizer chip set.

Simultaneously, RCA, GE, Timex and Hitachi were making advances in the development of low power digital displays. Monsanto had introduced the first light emitting diode (LED) display in 1969. Although many times lower-powered and less bulky than the vacuum tube-based displays of the day, LEDs were still power hungry for battery operated equipment. The above mentioned companies looked to the new liquid crystal display (LCD) technology for the

answer. Today, LCDs are common in watches, calculators, cell phones and communications equipment.

In the 1980s, with the IC synthesizer technology now fully developed and available very inexpensively, receiver manufacturers began to use this technique to generate local oscillator signals with digital precision. This, of course, gave us our first accurately-tuned, synthesized, digital-readout receiver. Sony was one of the first to produce such a receiver in their now-famous ICF-2001. The revolutionary features of this receiver, together with its relatively low cost (around in the \$300-400 range) caused quite a stir in the professional and military communications' world. It was a glimpse into the future of what was to come.

Today, in 2001, highly accurate, synthesized, digital display receivers are commonplace. Stereos, communication receivers, cellular phones and even boomboxes utilize the technology. Today, it is truly amazing how rapidly technology evolves into everyday products.

Great Moments in Radio's History

In Part One we have seen the tremendous developments the radio underwent in its first 100 years, from 1890 to the 1990s – evolving from a scientific curiosity to mass media, feeding the world. Below is a timeline of important events in the development of radio.

RADIO TIMELINE

1876	Bell invents telephone
1883	Edison invents the Edison effect
1886	Hertz produced and detected electric waves
1894	Lodge invents Coherer with 200 mile range
1897	J.J.Thompson discovers electron
1900	Poulsen invents Poulsen Arc
1901	Marconi sends signal from UK to Newfoundland
1906	DeForest invents triode
1906	Catwhisker crystal detector invented
1906	RF Continuous-wave alternator developed
1912	Armstrong invents radio-frequency generator
1918	Armstrong invents superheterodyne
1924	RCA superheterodyne hit stores in March
1933	Armstrong invents F.M.
1955	Wadley Loop – Racal RA 17
1981	Consumer Synthesized Receiver – Sony IC-2001
YOU ARE HERE – At the End of Part 1	
1995	Digital Signal Processing Receiver
2001	First Software Radio Chips
2010	????????????????????

Next Time - Part Deux

The advancements in digital electronics, coupled with the almost unbelievable developments in microcircuit technology, were to lead receiver design into the entirely new design concept of digital signal processing (DSP). DSP, the developments of software receiver chips, and what's next will be the topics for Part Two. Also, you won't want to miss a no-holds-barred look into the radio industry from one of the people who help shape it: Bob Grove. In a question and answer session, Bob will give his unique, first-hand perspective on the radio industry: past, present and future.

Acknowledgement

I'd like to thank Mr. H. Simmons, historian of vacuum tube technology and all aspects of radio circuitry, for his great assistance in helping write this feature. Harve has actually participated in many areas of technology to the modern integrated circuit. However, his recollection of the tube era says it all – "... the smell reaching anyone who ventured into an establishment where radios were used or repaired, was very special to me (and I am sure to others as well), because that smell of shellac and phenolic plastic invoked the very mystery and fun of radio."

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The History and Future of Radio – Part 2

By Dr. John F. Catalano

Last month we saw how radio started its evolution as the quirky, black magic mix of homemade parts. We saw how radio's development was inextricably tied to the development, standardization and commercialization of electronic components, such as the vacuum tube.

It has been a fact of life in the communications industry that it is "technology limited." In other words, most communications users can conceive of new, more flexible and convenient methods of radio communications. But, as we saw last time, until the advent of the vacuum tube amplifier, radio communications remained in the dark ages. Armstrong's superheterodyne radio circuit was only made possible by the commercial and technical development of the vacuum tube industry.

Let's look at an updated version of our radio time line from last time:

RADIO TIMELINE

1876	Bell invents telephone
1883	Edison invents the Edison effect
1886	Hertz produced and detected electric waves
1894	Lodge invents Coherer with 200 mile range
1897	J.J.Thompson discovers electron
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1918	Armstrong invents superheterodyne
1924	RCA superheterodyne hits stores in March
1933	Armstrong invents F.M.
1955	Wadley Loop – Rocal RA 17
1956	Germanium transistor commercialized
1976	Personal Computer Market Born
1981	Consumer Synthesized Receiver-Sony IC-2001
> YOU ARE HERE – At the End of Part 1	
1986	Cellular Phone Becomes International Business
1995	Digital Signal Processing Receiver
2001	First Software Radio Chips
????????????????	

The major effect that the development of the component called the coherer made on radio is clear. I'm sure that in 1901 Marconi would have given us no argument. Then it was the development of the crystal detector that pushed radio. And finally, vacuum tube technology development led the way as radio communications developed, until the last part of the 20th century.

However, even looking at radio's most recent past clearly shows that component and manufacturing technologies have dictated the resulting radio communications products.

Notice that for Part Two of this feature, we have added three items to the time line in 1956,

1976 and 1986. We've added these items in part two because they are the "drivers" of radio technology of today. We believe that they will continue to define radio for the foreseeable future.

As we concluded last time, the advancements in digital electronics, coupled with the almost unbelievable developments in microcircuit technology, led receiver design into the entirely new design concept of digital signal processing (DSP).

But DSP owes its very existence to the Personal Computer industry. Let's go back to around 1950 and see how today's DSP radio technology owes its being to a totally unconnected industry.

The year is 1948 and people at Bell Labs show the world that a cool, small lump of solid material can perform the functions of a hot, bulky vacuum tube. Bell Telephone was looking for a replacement for their much-used mechanical relay. Most people who read the *New York Times* report of that lump, later called the transistor, did not realize its long-lasting significance as an electronic component. Far fewer realized that it was about to introduce true mass production methods to electronic component manufacturing.

But physicists had been predicting the possibility of just such a solid state amplifying device for over thirty years. In fact, the famous 1906 cat's whisker lead/galena detector was later shown to function because of similar junction mechanisms that allowed the 1948 Bell Lab's transistor to function.

By the mid-1950s a number of these transistor researchers established businesses to commercialize the newly developed transistor technology. The going was hard. Due to impurities in the materials, instabilities and inconsistent components resulted. Not exactly the stable, repeatable product that is required for a profitable business!

The work continued nonetheless, though it sometimes felt like black magic as all the talented scientists and engineers struggled to learn about the critical effects of ultra cleanliness and material purity in manufacturing. Additionally, they were still trying to electrically tame the transistor. After a change of material from germanium to the better-behaved silicon, the transistor forces at last began to win battles over the entrenched vacuum-tube empire.

In the late 1960s, after stable manufacturing of single transistors at last became the norm, transistors began to replace tubes in many applications. Transistor companies started to look for ways to expand transistor and associated manufacturing technology to new products. Companies like Texas Instruments proposed fabricating more than just a single transistor. They attempted to fabricate whole functioning circuits.

Here, instead of each transistor being made

and packaged as a single device, the idea was to manufacture a number of transistors and resistors on the silicon. Then, using the same micro-sized "wire," connect them all together to form an operating circuit, such as an amplifier. It was called the Integrated Circuit, or IC for short. Thus the concept of today's microchip was born.

As the years went by the IC industry fine-tuned their technology and manufacturing. The result was the ability to cram many smaller devices on the same amount of silicon. This had a two-fold effect. First, more and more complex circuits were becoming possible. But, just as important, was the fact that since the amount of basic material used was relatively constant, and many circuits could be made at once, the costs did not go up directly with circuit complexity. In fact, cost per function went down!

For years this industry – now called the semiconductor industry after the class of material used to fabricate these devices – just kept making standard devices. Major semiconductor IC products until 1980, listed by production volume, included: simple logic gates, operational amplifiers, power amplifiers, clocks, frequency synthesizers, timers and phase lock loops.

Meanwhile, the semiconductor companies kept their researchers working on making smaller, higher device density ICs, while increasing their operational speeds. At the time, it was a technological answer, looking for a question. There was no product need for a large number (millions) of devices on a chip.

The PC – The Semiconductor Industry's Dream

In the mid-1970s home computers such as the Apple and Atari began to hit the market. These computers utilized the first of a new type of IC called the microprocessor. Early microprocessors were developed by expanding and combining digital logic ICs. Although not a trivial matter, the first processors were made by a relative small new company, MOS Technology. Most people who bought these early computers confessed to not having a real need for them and initial quantities were too low to attract the big semiconductor companies. But things were about to change.

When IBM announced the PC, it caught many people in the semiconductor industry by surprise, except for another relatively new company – Intel. Intel had been working away at microprocessor architecture for a number of years and was IBM's choice. The first IBM PC had an 8086 microprocessor, running at less than 10 MHz. But the race was on.

History shows that for almost the next twenty years, a human effort hundreds of times greater than getting a man to the moon was directed at microprocessor development. By the

last decade of the 20th century, processor speeds have become so fast that they approximate real-time calculations. In other words, to the user, complex calculations could be performed with little perceptible delay. In fact, not just calculations, but full emulation of electronic circuit functions were now possible. Could these special processors be used in place of real component-based circuits?

Audio DSP – A Reality

The answer demonstrated first by Texas Instruments and now many other companies including Analog Devices was – Yes! However, since the required speed of the processor is directly related to the frequency of the signal being processed, the first Digital Signal Processing (DSP) chips targeted audio applications where the speeds were limited to the 20 kHz range.

Figure 1 shows a typical block diagram of a receiver using DSP audio applications. Once the analog audio signal is digitized by an Analog to Digital converter (A/D), all audio filtering can be performed by mathematical functions. For example, a low pass filter function can be emulated by the processor if the stop frequency and response curve is defined by a formula and stored in the processor's memory.

By changing the formula, you can instantly convert the DSP to a different type of audio filter, say bandpass. By changing the coefficients of the variables in the formula, parameters of the filter can be adjusted. This is made simple by storing all the various filter parameters in memory. Then it is a simple matter of calling them up by filter name when needed. The result is like having a bank of razor sharp audio filters at your disposal. The only difference is the tiny size and cost of the DSP.

Audio DSPs became commonplace in many military and professional communications equipment. This led directly to a whole generation of PC sound cards based on the same DSP chips. Today, the capabilities of these DSP-based PC sound cards have been greatly expanded. Be assured that if you purchased a PC in the past few years you have been using a digital signal processor without even knowing it.

Another very useful function of DSP chips can be the relative easy way they can be used to decode various forms of digital signals. By plugging in RTTY, SITOR, AMTOR or any other digital mode, these DSP chips become small, inexpensive, flexible decoders. Not bad for an almost free added extra.

Why Not RF DSP?

Not known for their slow thinking, the semiconductor companies launched an all-out attempt to extend the DSP function from the slower au-

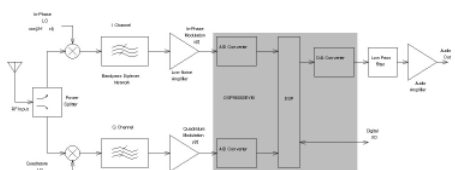


Figure 1 – Block Diagram of Receiver Using DSP in Audio Stages

dio stages to the faster RF signal stages. In this way the majority of any receiver could be reduced to a DSP chip, or chips. Great benefits in operational flexibility, cost and manufacturing could be realized. Since Armstrong's superheterodyne circuit is still widely used with intermediate frequencies (IF) of 70 MHz, 10 MHz and 455 kHz, these became the initial target speeds for DSP device developers.

Figure 2 is a block diagram of a full DSP receiver. The same A/D approach is used as with the audio DSP. However, this A/D converter's performance must be much higher in order to follow the higher frequency rf signal. This DSP now allows the same razor sharp, completely user-definable filtering for the rf stages, as we saw (or heard) in the audio DSP application. The use of DSP in the rf stages allows us to cut out co-channel interference, a major operational need given our over-crowded VHF/UHF radio spectrum. All this at a very low cost!

In addition, due to it being DSP throughout

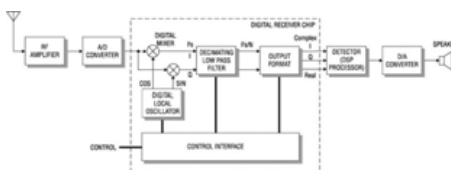


Figure 2 – Block Diagram Full DSP Receiver from www.pentek.com

its design, it can accommodate, via software, a multiple of signal types including TDMA, CDMA, GSM and AMPS!

The first DSP chips used in the RF circuits created enough digital noise to greatly limit their usefulness except in strong signal environments. Since then much work has been done to isolate and reduce digital clock signals from getting in the way of the intended target signals. Also there is an ongoing effort to increase the resolution and speed of the A/D converters.

The Software Radio Chip

With the lure of the ever-expanding cellular phone market, semiconductor manufacturers have set their goal for the 21st Century on a totally software reconfigurable radio. Their logic goes like this: A number of different frequencies, modulation methods and standards are used throughout the cellular phone/pager world. Their goal is to make a chip that can be used for any and all systems by just a software programming effort. This would allow cellular phone companies to make tens of millions of one radio. Then, depending on the country in which it is being sold, the radio can be software programmed to match the standards. No worry

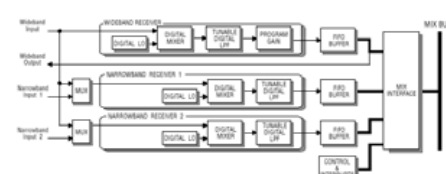


Figure 3 – Universal Soft Radio System Concept – Receiver on top – Transmitter on bottom.

about where it is to be used, or even obsolescence.

Even wilder possibilities include fabricating "universal soft radio" receivers and transmitters. These then could be used for *any* radio application. See Figure 3. Move over, Captain Kirk! I'm sure that the soft radio concept has brought a smile to many telecom CEOs and CFOs.

But Is It Possible?

Companies and universities have been working on the soft radio concept since the middle 1990s. Figure 4 shows Pentek's 4272 Multiband Digital Receiver which features: sampling rates to 70 MHz, one wideband and two narrow band receivers, dynamic range of 70 dB and 0.008 Hz tuning resolution. Check the free audio/slide seminar on their website <http://www.pentek.com> for a very good technical treatment of software radio design. Many of the semiconductor companies named at this site for functional block chips are working on a totally integrated software radio solution.

Although not yet fully integrated into a single package, its major functions should be available in a chip set by the end of 2001. A number of companies are hard at work to meet their announced product goal of 4th quarter 2001. Even if they miss by a year, when it does happen, this next technology leap promises to revolutionize radio communications and make products that are only today's dreams, into realities ... and probably commodities.

Welcome to the 21st Century and the future of radio.

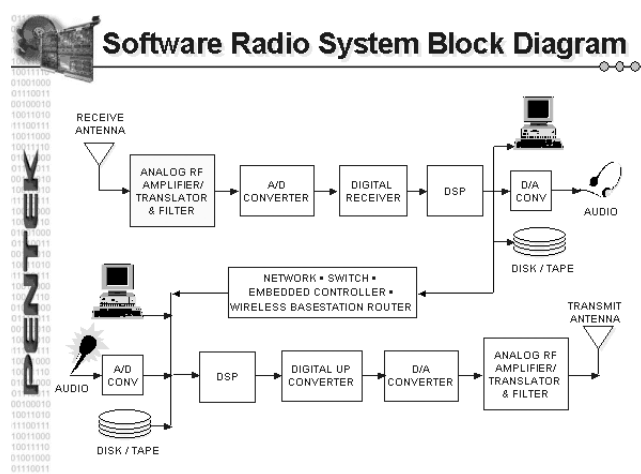


Figure 4 – Pentek's 4272 Multiband Digital Receiver Block Diagram